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Evaluation of Different Dietary Strategies on Body Composition in Individuals with Obesity

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Abstract
Obesity is a global health challenge. This study evaluated the effects of 4 dietary strategies on the body composition. Where 200 volunteers from southern Brazil were evaluated, 100 men and 100 women, between the ages of 20 and 50 and with a body mass index (BMI) equal to or greater than 30 kg/m2. Divided into 4 groups of dietary interventions: G1 - control diet, G2 - low-carbohydrate high-fat (LCHF), G3 - control diet with intermittent fasting (IF), G4 - low-carbohydrate high-fat with intermittent fasting (LCHF + IF). For 6 months, patients were monitored according to their body weight (BW), BMI, waist circumference (WC), body fat percentage (%BF), lean body mass (LBM), systolic blood pressure (SBP), blood glucose, and answered an assessment of adherence and satisfaction. The data was submitted to mixed linear model and multivariate analysis. No significant reduction in BW was observed, but all groups showed a reduction in WC. The caloric restriction with carbohydrate reduction (LCHF) and the application of IF caused a reduction in WC and %BF and resulted in improvement in glucose and SBP. Diets that include the application of LCHF (G2) and the use of IF (G4) show faster results and can end up generating more motivation to continue the diet. The application of an LCHF diet with IF protocols (G4) shows that there is indeed a potentiation of the results through IF application. IF was associated with the patients' reduction in appetite, improved mood and well-being, and intention to continue the diet.

Keywords : calorie restriction, diet, intermittent fasting, obesity

Introduction

Obesity is considered one of the greatest challenges to global health today. Although recognized as a chronic, non-communicable disease, it has reached epidemic proportions (Ealey et al., 2021). This disease adversely impacts population health, poses infrastructure challenges, significantly increases healthcare expenses, and incurs additional economic costs through loss of worker productivity, increased disability, and premature loss of lives (WHO, 2021).

Obesity and overweight can be defined as the excessive accumulation of fat that impairs health (WHO, 2021). Excess weight is observed in more than half of Brazilian adults, with obesity affecting 24% of women and 17% of men. In Brazil, inadequate nutrition indirectly and directly impacts premature mortality for both women and men aged 30 to 69 years, with obesity costs exceeding 1 billion Brazilian reais (Figueiredo et al., 2021).

The excess of body fat leads to an increased development of non-communicable chronic diseases. Patients with obesity are at risk of developing comorbidities such as type 2 diabetes mellitus (2DM), cardiovascular diseases, musculoskeletal disorders, systemic arterial hypertension, neuro-metabolic diseases, certain types of cancers, and responsible for over 3.5 million deaths annually (Khanna & Rehman, 2021).

Controlling obesity, a multifactorial disease, requires efforts from various professionals, where nutrition plays a fundamental role in understanding the disease, its prevention, and control.

Therefore, diets containing low levels of carbohydrates combined with high levels of fat (LCHF) have shown interesting results concerning weight loss and metabolic improvement (Ridker, 2002; Zimmet & Thomas, 2003; Khanna & Rehman, 2021). The prescription of the LCHF diet as a weight loss strategy has been known since 1860 (Bantin, 2020). Although widely discussed within nutrition, these diets generally involve reducing the carbohydrate intake, leading to an increase in the relative proportion of energy derived from protein and fat (Noakes & Windt, 2017).

In addition to reducing carbohydrates in the diet, another method that has gained interest among healthcare professionals is Intermittent Fasting (IF). This method aims to restrict the feeding period to a few hours a day, promoting improvements in metabolism, reduction of body fat, and other benefits (Varady et al., 2010; Ganesan et al., 2018).

During fasting, the body goes without food for an extended period, consequently, it stops storing glucose, reducing circulating insulin levels, promoting lipolysis, and fat oxidation (Anson et al., 2003). When this occurs, the activation of another hormone, called glucagon, is required. Glucagon acts on the release of glycogen, a form of energy stored in the liver and muscles, though in small quantities. After depleting hepatic glycogen reserves, the body activates fat breakdown, lipolysis, to meet its energy needs and maintain blood glucose levels (Boczek & Kapiloff, 2020). This mechanism can contribute to weight loss.

Different dietary strategies can be used in the treatment of individuals with obesity, including caloric restriction, LCHF diets, and combining diets with intermittent fasting practice, among others. Therefore, the present study aimed to analyze the effects of isolated or combined use of dietary interventions, LCHF diet and IF, on the body composition of obese adults in the southern region of Brazil.

The authors propose as study hypotheses whether LCHF and IF dietary interventions assist women and men with obesity in losing weight similarly and if there is a diet that improves body composition according to sex and age.

Materials and Methods

A randomized controlled clinical trial was conducted, involving 200 patients between the ages of 20 and 50 years, with a Body Mass Index (BMI) $\geq$30 kg/m². These participants were followed for 6 months, with diet and body composition monitoring every 15 days. They were divided into four groups of 50 individuals each, comprising 25 males and 25 females, who underwent different dietary interventions (G1 = Control Diet; G2 = LCHF Diet; G3 = Control Diet + IF; G4 = LCHF + IF).

The sample size in each of the dietary intervention groups was determined based on a priori expectations of variability in the controlled study variables: body weight (BW), waist circumference (WC), percentage of body fat (%BF), lean body mass (LBM), the number of treatments to be evaluated, and a balance between the chances of committing a type I statistical error (rejecting H0 when H0 is actually true, as defined by the significance level of the test) and the chances of committing a type II statistical error (not rejecting H0 when H0 is actually false - defined by the test power).

Regarding the latter factor, statistical power can be considered as the probability of detecting the effect of a test when there is, in fact, such an effect. Therefore, the borderline detection zone for the experiment was set at Delta = 5, representing the minimum expected detectable difference in treatment comparison. The significance level was set at p-value = 0.05, and the overall standard deviation of the study was fixed at 8, resulting in a statistical power of 0.74 for a sample size of 50 individuals per treatment (Basavarajaiah & Murthy, 2020; Montgomery, 2020).

The project was approved by the research ethics committee through the Brazil Platform (opinion number 3.539.808) and by the UNINI ethics committee (minutes n°CR-032).

For dietary delineation, the caloric needs of everyone were first determined using the Harris and Benedict equation - HBE (Harris & Benedict, 1914), differentiating between males and females. After calculation, the result of Basal Metabolic Rate (BMR) was multiplied by the physical activity frequency (1.20 - little daily exercise). Subsequently, four treatments with distinct dietary strategies were applied (Figure 1).

In the Control Diet (G1), patients received a hypocaloric diet, maintaining proportions of 55% carbohydrates, 25% fat, and 20% protein in the diet.

In the LCHF Diet (G2), individuals in this group underwent a diet with a low percentage of carbohydrates and a high fat content, consisting of 20% carbohydrates, 40% fat, and 40% protein, based on the dietary recommendation of ingesting fewer than 150 grams of carbohydrates per day.

In the Control Diet with IF (G3), patients followed the same diet proportions as the control group but implemented a 16-hour fasting period twice a week (from 8:00 PM to 12:00 PM) with only water intake, performed on non-consecutive days.

In the LCHF Diet with IF (G4), patients received the hypocaloric LCHF diet (20% carbohydrates + 40% fat + 40% protein) combined with a 16-hour IF (8:00 PM to 12:00 PM) twice a week, on non-consecutive days, consuming only water during this period throughout the evaluation period.

It is important to note that, in the IF treatments, the caloric intake on the fasting day was the same as on the other days, only organized differently throughout the day according to the fasting schedule.

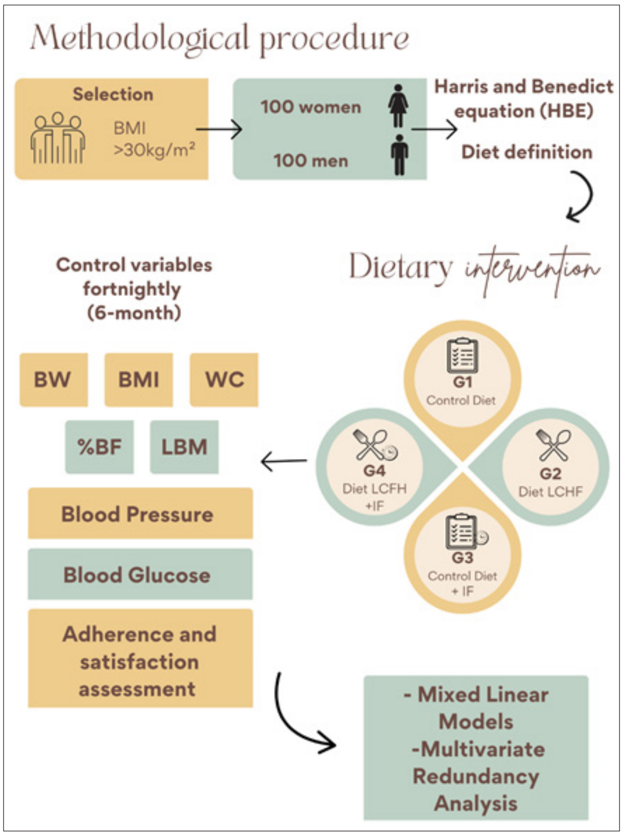

Figure 1: Methodological procedure of the study. Selection of 200 patients, the definition of the diet was performed based on the calculation using the Harris and Benedict equation (HBE), and applied to different groups: Control Diet (G1), Low Carbohydrate High Fat Diet (LCHF) (G2), and the combination of Intermittent Fasting with the standard diet (G3) and LCHF (G4). Data related to Body Weight (BW), Body Mass Index (BMI), Waist Circumference (WC), Percentage of Body Fat (%BF), Lean Body Mass (LBM), Blood Pressure, Blood Glucose, and adherence and satisfaction assessment were monitored. The data were analyzed using the statistical techniques of Mixed Linear Models and Multivariate Redundancy Analysis.

In the assessment of the efficiency of the dietary intervention (Figure 1), data from eight control variables were monitored over the 6-month period: body weight (BW), BMI, waist circumference (WC), percentage of body fat (%BF), lean body mass (LBM), systemic blood pressure, and blood glucose.

The investigative instruments utilized included a measuring tape for circumference measurements (Model 201 - Seca) with a length of 205 cm; a Tetrapolar bioimpedance scale (Tanita BC 601) with a precision of 100 grams; a digital blood pressure monitor (Omron HEM-7122), and a Glucose Meter Kit (Free Lite Test G-Tech).

The patients also completed an assessment of their level of adherence and satisfaction regarding the diet.

The effects of the different dietary interventions on the patients' metabolic response and body composition (Figure 1) were evaluated through descriptive analysis (calculation of mean and standard deviation) and were subjected to Mixed Linear Models (statistical test). The use of a mixed linear model for data analysis requires the identification of random effects (associated with individuals), the selection of fixed effects (associated with average response profiles), and the choice of covariances between individuals. For this purpose, the inclusion of random effects in the model was based on the analysis of individual response profiles for each group, with the average response profile graph explaining the behavior of mean responses over time and choosing the degree of the polynomial to be fitted. The covariance structures were obtained from the individual profile graphs and the estimated covariance matrix of the data (Laird & Ware, 1982).

Regarding the data on diet satisfaction, a multivariate redundancy analysis based on distance was performed (Oksanen et al., 2020) using data collected through a multiple-response questionnaire. The constructed distance matrix used the Mahalanobis distance, which standardized the range of variation of variables from different sources into a common interval. The significance of these analyses was evaluated through permutation tests (ANOVA.CCA) (Oksanen et al., 2020). This analysis was divided into two experiments (experiment 1 and experiment 2), with multiple response variables structured into one matrix and explanatory variables structured into a second matrix.

In experiment 1, the variation of diets was tested on 9 measured variables for each patient, namely: BW, height, BMI, WC, %BF, systolic blood pressure (SBP), diastolic blood pressure (DBP), and glucose levels. These response variables were compared with patient (P), sex, age, type of diet (E), and collection day (CD).

In experiment 2, the results of ten questions from the questionnaire were evaluated:

- I felt hungrier than usual (FHTU);
- Lack of time made the diet difficult (LTDD);
- Physical discomfort after starting the diet (PDSD);
- Psychological problems after starting the diet (PPSD);
- I am enjoying the diet prescribed to me (IED);
- I intend to maintain the diet (IMD);
- I would like to switch to a different diet (SDD);
- I thought about giving up on the diet (GUD);
- My mood worsened with the diet (MWD);
- My mood improved with the diet (MID).

These response variables from experiment 2 were compared with data related to sex, age, type of dietary intervention, and the number of days on which the diet was not followed (NDNFD).

Results

The profile of patients undergoing different dietary interventions consisted of adults with a mean age of 36 ± 6.3 years. The initial mean body weight (BW) was 90 ± 10.12 kg for women and 108 ± 14.2 kg for men, while the mean BMI was 33 ± 2.7 kg/m² and 34 ± 2.6 kg/m², respectively.

Statistically, no significant effect on BW over time was observed in all evaluated treatments (F = 2.13; p-value = 0 | Figure 2A). While some individual patients experienced weight loss, overall, this loss was not significant. At the beginning, it is evident that individuals adhered to the diet, but towards the end, the increase in the confidence interval (CI) (hatched area in Figure 2A) indicates a deviation from the diet.

Regarding WC, a significant reduction effect was observed in all evaluated treatments, as indicated by the F value (F = 1277.7), which represents the ratio between the model and the error. A higher F value indicates greater data dispersion, and the low p-value (<2.2e-16) indicates a low probability of no differences between before and after the diets, based on the collected data (Figure 2B). The treatments G1 - G2 (p-value = 1.2e-9); G1 - G3 (p-value = 1.9e-9); G1 - G4 (p-value = 8.4e-10); G4 - G2 (p-value < 2.2e-16), and G4 - G3 (p-value < 2.2e-16) were significantly different from each other. Only the treatments G2 - G3 did not show significant differences between them (p-value = 0.3). Treatments G2 and G4 demonstrated a greater response in reducing WC, as observed in the decline. All treatments remained stable throughout the entire period (constant CI throughout the series).

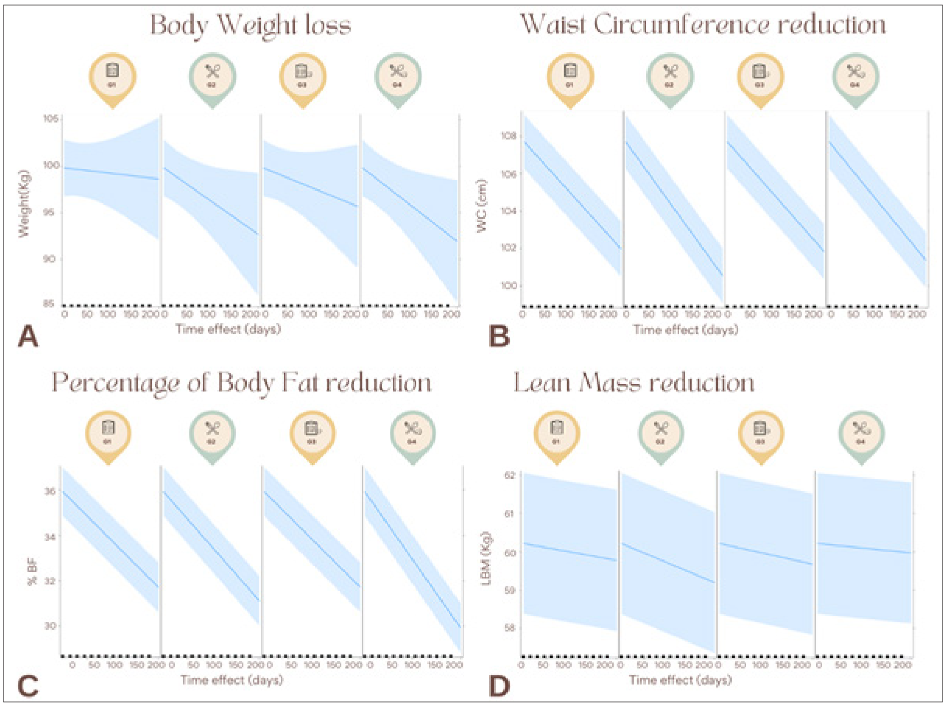

Figure 2: General comparison of the mixed linear model for Body Weight loss (A), Waist Circumference reduction (B), Percentage of Body Fat reduction (C), and Lean Mass reduction (D), by type of treatment and temporal effect. Where G1 represents the Control Diet, G2 the LCHF Diet, G3 the Control Diet with IF, and G4 the LCHF Diet with IF. The line represents the mean of the variables, and the hatched area represents the 95% Confidence Interval (CI) in the mixed linear model.

Regarding %BF, there was also a significant reduction effect in all evaluated treatments (F = 1742.5; p-value < 2.2e-16 | Figure 2C). Treatments G1 - G3 (p-value = 0.006); G1 - G4 (p-value = 0.002), and G2 - G3 (p-value = 0.04) were significantly different from each other. The other treatments did not show significant differences among them (p-value > 0.05). Analysis of the decline in the mean %BF indicated a greater decrease in the dietary interventions G2 and G4, making them the most efficient interventions, with G4 showing the best results for %BF reduction (highest decrease).

In the case of the percentage of lean mass, a significant reduction effect was also observed in all evaluated treatments (F = 91.9; p-value < 2.2e-16 | Figure 2D). Treatments G1 - G2 (p-value < 2.2e-16); G1 - G3 (p-value < 2.2e-16); G1 - G4 (p-value < 2.2e-16); G4 - G2 (p-value < 2.2e-16), and G4 - G3 (p-value < 2.2e-16) were significantly different from each other. Only treatments G2 - G3 did not show significant differences (p-value = 0.1185). Dietary intervention G2 showed a trend of greater reduction, although the wide CI should be noted.

The multivariate analysis showed a significant difference between treatments (G2, G3, and G4) in experiment 1 (Figure 3). These treatments presented a distribution along the second axis. The second axis explained 16.56% of the observed variation. The variation along this axis was better explained by the age of the participants and the collection day. On the other hand, the first axis explained 32.31% of the observed variation. Along this axis, the interviewed individuals were divided into these groups, mainly based on LBM and %BF.

In summary, height, WC, and sex did not have an effect on dietary interventions. The overlaid ellipses (Figure 3) show that there was no significant difference between the treatment groups, but some trends were observed. Older individuals showed less weight loss and less %BF reduction with increasing age during the different dietary interventions; they also lost less LBM during the diets but had higher glucose, DBP, and SBP values.

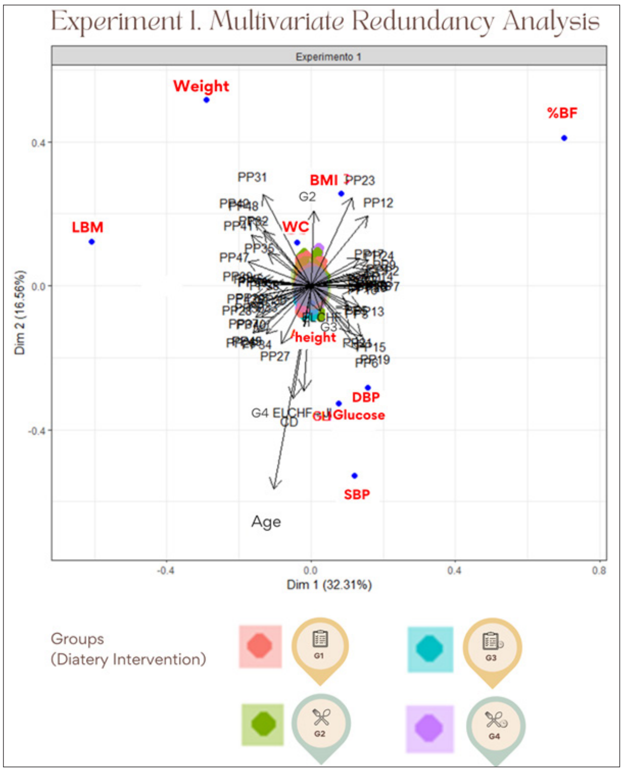

Figure 3: Experiment 1. Multivariate redundancy analysis applied to assess the variation of dietary interventions, where G1 represents the Control Diet, G2 the LCHF Diet, G3 the Control Diet with IF, and G4 the LCHF Diet with IF, concerning the 9 measured variables of each patient: Body Weight (BW), height, Lean Body Mass (LBM), Waist Circumference (WC), Percentage of Body Fat (%BF), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), and glucose (in red). These response variables were compared with patient (P), sex, age, type of diet (E), and collection day (CD), represented by vectors in this figure.

Experiment 2 showed a significant difference concerning the number of days the interviewees deviated from the diet, followed by patient, experiment, collection day (CD), and age (Figure 4). In this experiment, axis 1 explained 27.92% of the variance. This variation was better explained by the time the interviewees deviated from the diet for questions B and D, indicating LTDD and PPSD, respectively. The vectors representing the experiments were distributed along the bisector of the even quadrants. In experiment 1 (Figure 3), dietary interventions G2 and G4 had similar and opposite effects to dietary intervention G3.

In experiment 2 (Figure 4), an association was detected between G2 and G4 with MID, IED, and IMD. On the contrary, dietary intervention G2 showed an association with MWD, FHTU, PDSD, and PPSD.

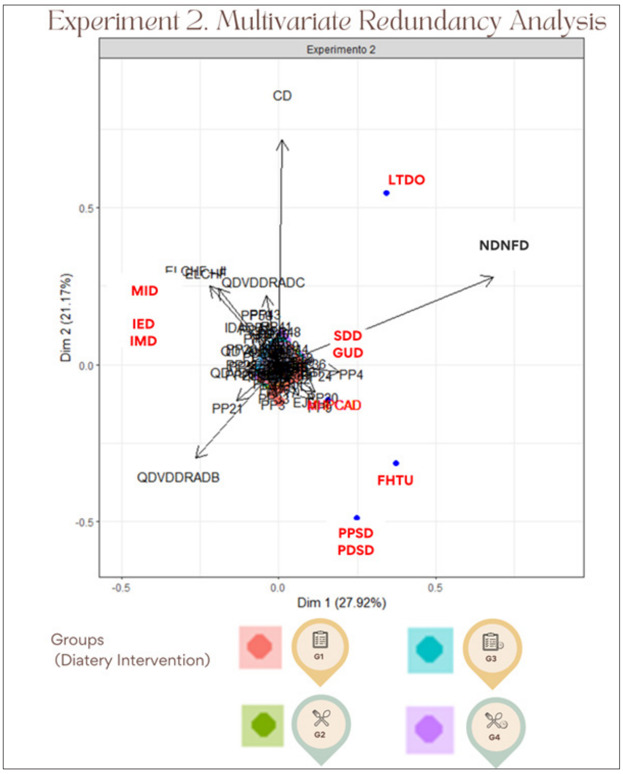

Figure 4: Experiment 2. Multivariate redundancy analysis applied to assess the variation of dietary interventions, where G1 represents the Control Diet, G2 the LCHF Diet, G3 the Control Diet with IF, and G4 the LCHF Diet with IF, regarding the perception of each patient through a questionnaire composed of 10 questions applied as follows:

1. I felt hungrier than usual (FHTU);
2. Lack of time made the diet difficult (LTDD);
3. Physical discomfort after starting the diet (PDSD);
4. Psychological problems after starting the diet (PPSD);
5. I am enjoying the diet prescribed to me (IED);
6. I intend to maintain the diet (IMD);
7. I would like to switch to a different diet (SDD);
8. I thought about giving up on the diet (GUD);
9. My mood worsened with the diet (MWD);
10. My mood improved with the diet (MID) (in red). These response variables were compared with patient (P), sex, age, type of diet (E), and collection day (CD), represented by vectors in the figure.

Discussion

In the present study, a reduction in both systolic and diastolic blood pressure, as well as serum glucose concentrations, was observed in all interventions (G1, G2, G3, and G4) for both women and men. Weight gain tends to lead to changes in blood pressure, while weight loss is associated with the normalization of blood pressure.

The use of different dietary strategies in individuals with obesity can contribute to changes in body composition (Astrup & Hjorth, 2017). Weight loss can reduce systolic and diastolic blood pressure, and the mechanisms that assist in reducing systemic blood pressure include alterations in vascular structure and function and improvements in insulin resistance (IR) (Rayalam et al., 2008).

Excess weight can be related to elevated levels of systemic blood pressure, and an increased waist circumference is associated with a higher risk of cardiovascular disease and systemic hypertension (Lima et al., 2021).

In a study conducted with 277 individuals with an average age of 45 years in Brazil, a positive correlation was observed between anthropometric data and blood pressures (BMI with systolic and diastolic blood pressure, and waist circumference with systolic and diastolic blood pressure), indicating that higher anthropometric data were associated with higher blood pressures. There was a strong correlation between waist circumference and systolic blood pressure (Lima et al., 2021).

Insulin resistance (IR) caused by overweight and obesity can be a gateway to metabolic syndrome, which involves the co-occurrence of excess abdominal fat, elevated blood pressure, atherogenic dyslipidemia, and hyperglycemia (Alberti et al., 2009; WHO, 2021). From an epidemiological perspective, the presence of metabolic syndrome increases general mortality by 1.5 times and cardiovascular mortality by around 2.5 times (Carvalho et al., 2005; WHO, 2021).

In the present study, caloric restriction positively reflected in the reduction of waist circumference and body fat percentage (%BF), which showed significant reduction in all treatments (G1, G2, G3, and G4) for both women and men. Caloric restriction is a well-established intervention for obesity treatment, and its application produces visible early effects in improving metabolic patterns, with noticeable results seen with a 5% loss of initial body weight, further magnifying its effect with continued weight loss. Individuals with excess weight and IR also benefit from attenuating glucose-induced lipid synthesis in adipose tissue, especially when caloric restriction is combined with a high-quality nutrient diet (Schutte et al., 2022).

Treatments G2 and G4 demonstrated a greater response in reducing waist circumference. In the analysis of the decline in %BF averages, intervention G4 showed the best results for %BF reduction. In these calorie-restricted groups with reduced carbohydrates and increased good fats and protein in the diet, reductions in waist circumference and %BF were greater, with intermittent fasting magnifying %BF reduction in G4.

Reducing abdominal fat represented by waist circumference and %BF reduction prevents and reduces various comorbidities, being more important than the weight loss itself, bringing about several beneficial metabolic effects. Reducing adipose tissue improves body energy homeostasis, metabolism, insulin sensitivity, and reduces blood glucose, excessive inflammatory state, and may even lead to a reduction in systemic blood pressure (Fonseca, 2020; Abedpoor et al., 2022).

The evaluation of LCHF dietary intervention in a study with 122 patients also demonstrated a reduction in waist circumference and %BF. The same study also highlighted the usefulness of providing LCHF health promotion interventions in primary care settings (Myshak-Davis et al., 2022).

LCHF diets can provide more than just reductions in body weight; they can also promote reductions in %BF, diastolic blood pressure, serum triglyceride, and glucose concentrations, acting as a tool in controlling obesity (Pacca et al., 2018; Paoli et al., 2013), as seen in this study.

Greater adherence to LCHF interventions results in more significant improvements in laboratory and anthropometric outcomes in general, such as reduced BMI, systolic and diastolic blood pressures, glycosylated hemoglobin, fasting insulin, estimated glomerular filtration rate, and albumin-to-creatinine ratio (Myshak-Davis et al., 2022).

Although the LCHF diet presented positive results in obesity control in this study, other studies have shown that the quality of carbohydrates is more critical than just the quantity.

Observations in the Tsimané (aka Chimane) indigenous population in South America showed that they lead a traditional hunter-gatherer lifestyle, with their diet consisting of approximately 14% protein, 14% fat, and 72% carbohydrates. However, despite this seemingly high carbohydrate intake, this population has the lowest levels of chronic diseases ever recorded in any population. This study points out that the quality of carbohydrates seems to be a fundamental aspect to consider, not just the quantity (Kaplan et al., 2017).

In the application of LCHF diets, reducing carbohydrates activates two processes when glucose availability is declining: gluconeogenesis and ketogenesis. In a high-carbohydrate diet, glucose reserves in the liver and muscles are typically well-stored. In fasting conditions, blood glucose levels are kept stable by degrading glucose from hepatic glycogen. This process is regulated by the insulin/glucagon ratio. Low insulin levels ensure that relatively few fatty acids are stored in adipocytes, while fatty acid secretion through lipolysis maintains high levels of fatty acids in the bloodstream. This leads to a high degree of fatty acid oxidation and relatively low glucose oxidation (Brouns, 2018).

When following an LCHF diet, the amount of glucose absorbed into the bloodstream from food each day is insufficient to maintain glycogen stores in the liver and muscles. This results in a reduction of glycogen stores, reduced glucose release, and consequently, reduced blood glucose levels. The body experiences this as stress and will do everything it can to ensure maximum fatty acid burning, aiming to prevent the use of glucose, primarily required for the central nervous system and red blood cells (Brouns, 2018).

The application of LCHF in individuals with obesity and diabetes induces favorable effects on weight loss, glycemia, insulin, as well as some less-desirable effects, such as an increase in LDL (low-density lipoprotein) cholesterol and reduced vascular reactivity (Brouns, 2018).

The reduction in %BF and especially in waist circumference improves insulin resistance, and other studies have observed the same; their main justification lies in the reduction of visceral fat, which is primarily responsible for metabolic syndrome (Penna et al., 2020; Carvalho & Dos Santos, 2019). Ingesting fewer calories will initially result in weight or %BF loss, leading to favorable metabolic and functional changes (Brouns, 2018); thus, caloric restriction in the diet is a recommended practice in individuals with obesity, with good dietary habits and physical activity being essential to combat insulin resistance and reverse fat accumulation (Carvalho & Dos Santos, 2019).

Although in the present study, intermittent fasting (IF) used with the control diet (G3) did not achieve the same result that demonstrates the effectiveness of IF, the data from G4 show that there is indeed potentiation of results by the application of IF. Besides a balanced diet, the use of IF is considered by some as an alternative in combating the obesity epidemic, as it can help suppress hunger, improve the immune system, and reduce insulin resistance (Arbour et al., 2021), as well as improve body composition, systemic blood pressure, and glycemic control (Mohr et al., 2021).

In a study conducted with women and men aged 20 to 45 years with BMI between 25 and 30 kg/m² in the United States, the application of IF demonstrated a decrease in 24-hour glucose levels, as a reflection of intermittent caloric restriction, also resulting in reduced morning fasting glucose and insulin levels, increased LDL (low-density lipoprotein) and HDL (high-density lipoprotein) cholesterol levels in the morning, as well as increased levels of brain-derived neurotrophic factor (Jamshed et al., 2019).

Problems with adherence to the diet during the study period may explain the lack of a statistically significant relationship for weight loss. As other studies report, adherence to the diet tends to decrease over time (Austen, 2021). In this study, the indication by patients of a lack of time as a difficulty in maintaining the dietary intervention is highlighted.

The LCHF diet is considered challenging by many, with risks of low adherence (Brouns, 2018), while those who adhere to IF reported a reduction in appetite, increased energy, and on the other hand, some studies also reported weakness and headaches (Felaço et al., 2019).

In general, in this study, patients started the diet well, but data with a broad confidence interval showed that they became less involved and did not follow the diet. This is a behavior reported in other studies (Ealey et al., 2021), especially for diets that have a longer return. This may explain why G2 and G4 obtained better results and reported improved mood, greater approval of the diet, and an intention to continue it.

Another relevant aspect that should be mentioned in this discussion is the influence of an obesogenic environment, which hinders diet adherence. Although it was not a focus question in the questionnaire, several patients informally reported problems related to living in obesogenic environments and their influence on the diet. The contribution of the physical, cultural, industry, fast-food access, and media environment in the establishment of obesogenic environments (Souza & Oliveira, 2008).

Several patients in this study also reported psychological problems after starting the diet. Obesity is also a behavioral problem that requires organization and dietary planning, accompanied by a multidisciplinary team and psychological support (Vilhena et al., 2019; Oliveira et al., 2021).

It is worth mentioning here that the data collection in the present study every 15 days may have been excessive and, to some extent, hindering patient participation.

Furthermore, limitations in terms of a more detailed analysis with laboratory tests for a more comprehensive metabolic analysis, including insulin measurements, and consequently, the presence of insulin resistance and lipid blood profile, could aid in a better understanding of the functioning of each dietary intervention.

Conclusion

The present study demonstrated that obesity treatment goes far beyond aesthetic concerns, as the application of dietary interventions showed benefits in body composition.

Reducing abdominal fat represented by waist circumference (WC) reduction prevents and reduces various comorbidities, being more important than weight loss itself. Caloric restriction with reduced carbohydrates (LCHF) and the application of intermittent fasting (IF) in this study led to reductions in waist circumference and body fat percentage (%BF) and resulted in improvements in glucose, systolic and diastolic blood pressure (SBP and DBP). The reduction in %BF and waist circumference is capable of reducing SBP, DBP, glucose, and inducing changes in insulin resistance (IR).

The reduction in %BF and waist circumference alone will lead to favorable metabolic and functional changes, also improving insulin sensitivity. Good dietary habits are essential to combat insulin resistance and reverse fat accumulation.

Although the application of LCHF diets and IF in diets may be controversial, in the present study, the application of an LCHF diet with IF protocols (G4) demonstrated that there is indeed a potentiation of results by applying IF. Moreover, the application of IF was associated with reduced appetite, improved mood and well-being, and an intention to continue the diet. Diets that include the application of LCHF (G2) and IF (G4) show faster results and may generate more motivation for diet continuity.

It is noteworthy that several patients reported psychological problems after starting the diet. Obesity should be treated more comprehensively, combining healthy eating, exercise, and mental health care. A broader approach to health is necessary.

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